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Cost Analysis of Single-Level Lumbar Fusions

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Abstract

Study Design: Cost analysis of a retrospectively identified cohort of patients who had undergone primary single-level lumbar fusion at a single institution's orthopedic or neurosurgery department.

Objective: The purpose of this article is to analyze the determinants of direct costs for single-level lumbar fusions and identify potential areas for cost reduction.

Methods: Adult patients who underwent primary single-level lumbar fusion from fiscal years 2008 to 2012 were identified via administrative and departmental databases and were eligible for inclusion. Patients were excluded if they underwent multiple surgeries, had previous surgery at the same anatomic region, underwent corpectomy, kyphectomy, disc replacement, surgery for tumor or infection, or had incomplete cost data. Demographic data, surgical data, and direct cost data in the categories of supplies, services, room and care, and pharmacy, was collected for each patient.

Results: The cohort included 532 patients. Direct costs ranged from $8286 to $73 727 (median = $21 781; mean = $22 890 ± $6323). Surgical approach was an important determinant of cost. The mean direct cost was highest for the circumferential approach and lowest for posterior instrumented spinal fusions without an interbody cage. The difference in mean direct cost between transforaminal lumbar interbody fusions, anterior lumbar interbody fusions, and lateral transpsoas fusions was not statistically significant. Surgical supplies accounted for 44% of direct costs. Spinal implants were the primary component of supply costs (84.9%). Services accounted for 38% of direct costs and were highly dependent on operative time. Comorbidities were an important contributor to variance in the cost of care as evidenced by high variance in pharmacy costs and length of stay related to their management.

Conclusion: The costs of spinal surgeries are highly variable. Important cost drivers in our analysis included surgical approach, implants, operating room time, and length of hospital stay. Areas of high cost and high variance offer potential targets for cost savings and quality improvements.

Keywords

spine surgery, economic evaluation, health care spending, lumbar, spinal fusion, single-level

Introduction

Unsustainable health care spending in the United States has led to an increased emphasis on cost-effectiveness and value-based health care. Spine conditions account for a significant proportion of health care spending in the United States, and the use of health care resources for the diagnosis and treatment of these conditions is increasing more rapidly than other areas of health expenditures.[1] Between 1997 and 2005, there was a 65% increase in health care expenditures for patients with

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self-reported back and neck problems, yet no evidence of a corresponding improvement in self-assessed health status.[1] Both increased rates of spinal surgery and increased costs of performing these procedures have contributed to the dramatic increase in the total expenditures for spinal surgery. The rate of spinal fusions increased by 55% between 1979 and 1990,[2] by 220% between 1990 and 2001,[3] and by 73% between 1998 and 2006.[4] The cost of spinal fusions has also risen. Between 1998 and 2006, the cost of surgery increased by 191% for primary fusions and 272% for revision fusions. Rising costs, in combination with the increased rate of fusions, have led to a high overall rate of expenditure for spinal conditions. Between 1998 and 2006, total spending increased by 408% for primary spinal fusions and 535% for revision spinal procedures, resulting in a total expenditure for these procedures of $29.1 billion in 2006.[4] An increase in the number of patients seeking care for spine-related conditions has been cited as the primary reason for increased expenditures, as evidenced by a concomitant increase in the costs of nonoperative spine care.[1]

In addition to the increased costs and rates of spinal fusions, there is also a high amount of variance in the use of lumbar fusions between the United States and other countries, geographic regions within the United States, hospitals in the same region, and even individual surgeons at the same hospital.[5,6] A study of the Medicare population between 1992 and 2003 demonstrated a 20-fold variation in the rates of lumbar spinal fusion between the highest and lowest regional rates of the United States.[7] Some believe that this high variation of care shows a poor consensus on surgical indications for this procedure and suggests excessive rates of spinal fusion in some regions.[8]

In our current health care economy, where there is increasing competition for a limited health care dollar, it is essential to determine whether a health care intervention adds value to patient care—that is, whether the incremental cost for the intervention is justified by an incremental improvement in health-related benefits. Recent systematic reviews to assess value in spine surgery have demonstrated the high value for numerous operative interventions in spine care and have also identified interventions that are not reliably cost-effective.[9,10] Value in spine surgery may be optimized by improving clinical outcomes achieved and their durability, reducing complications and the need for revision surgeries, and reducing costs. In an effort to reduce costs, it is essential to identify the factors driving those costs and determine areas where cost savings may be achieved. The purpose of this article is to characterize the determinants of direct costs and report variance in the direct cost of care for single-level lumbar fusions.

Methods

Institutional review board approval was obtained prior to the collection of data. Adult patients who underwent primary single-level lumbar fusions between fiscal years 2008 and 2012 met inclusion criteria. All surgeries were performed by 1 of 10 spine surgeons from the orthopedic surgery and neurosurgery departments at a single institution. Patients were identified through hospital data using Current Procedural Terminology codes (Appendix A). Patients were excluded if they underwent multiple surgeries, had previous surgery at the same level, underwent corpectomy, kyphectomy, disc replacement surgery, surgery for tumor or infection, or had incomplete cost data.

A major inaccuracy of using administrative codes alone was that a significant number of cases coded as posterior spinal fusions included a posterior-based interbody fusion (posterior lumbar interbody fusions [PLIF] or transforaminal lumbar interbody fusions [TLIF]). To accurately categorize many cases, CPT codes were cross-referenced with the use of implants from our institution's surgical database to determine which posterior spinal fusions were performed with an interbody cage, and charts were reviewed when this could not be determined from our surgical database. The circumferential fusion group includes only cases in which both anterior and posterior procedures were performed on the same day. Circumferential fusions staged over separate days or separate admissions were not included in our analysis.

Demographic, surgical, and direct cost data was collected for each patient and separated into four categories: supplies, services, room and care, and pharmacy. All costs were incurred during the course of a single hospital admission. Postdischarge costs were not included in our analysis. Costs were identified by direct access to medical billing data. Cost outliers in each category were chart reviewed to improve accuracy. Direct costs rather than charges were used for this analysis. Indirect costs (eg, hospital administrative and facilities overhead, cost of house staff, health information management, accounting and billing, housekeeping, etc) were not included. Surgeon fees were billed separately and are therefore not included in the direct cost data. Anesthesia fees were considered a component of the operating room costs. Operative time included the total time the patient was in the operating room rather than time of incision to closure.

An analysis of variance (ANOVA) was performed to compare differences in costs between the 5 surgical approaches (posterior spinal fusion [PSF], anterior lumbar interbody fusion [ALIF], TLIF, combined approach/circumferential, lateral). The Tukey honest significant difference (HSD) method was used to perform pairwise comparisons between approach types. Costs were compared by approach as well as by cost category. These categories include: supplies, implants (a subcategory of supplies), services, room and care, pharmacy, and total direct costs. The differences in means for length of stay and operating room time were also compared between surgical approaches. Statistical analysis was performed both with the inclusion and exclusion of extreme outliers in the categories of total direct costs (costs >$50 000; $n = 1$), room and care (costs >$15 000; $n = 2$), and pharmacy (costs >$5000; $n = 2$), with the same conclusions achieved in both analyses. The Statistical Analysis System (SAS) version 9.3 was used to perform the analysis.

Table 1. Demographic Data.

Age, years, mean ± SD (range)	55 ± 13 (19-91)
Gender, female, n (%)	294 (55.3)
Diagnosis, n (%)	
Degenerative	282 (53.0)
Spondylolisthesis	211 (39.7)
Deformity	27 (5.1)
Trauma	12 (2.2)

Results

Seven hundred and two patients met inclusion criteria based on CPT codes. One hundred and sixty-nine patients were excluded based on clinical exclusion criteria and 1 was excluded for incomplete cost data. Five hundred and thirty-two patients met all criteria for our study. Average age was 55 years (range 19-91 years, SD = 13). Diagnoses included degenerative conditions, spondylolisthesis, deformity, and trauma (Table 1). TLIF was the most common surgical approach (48.5%), followed by posterior spinal fusion without interbody cage (PSF; 23.3%), circumferential (combined anterior or lateral and posterior) fusion (13.0%), ALIF alone (12.8%), and lateral transpsoas fusion ("lateral"—extreme lateral [XLIF]/direct lateral [DLIF]/lumbar lateral [LLIF]) alone (2.4%). Operating room time, hospital days, and admission to intensive care unit (ICU) for each approach are presented in Table 2. Table 3 presents cost categories and variance in utilization for individual components within each category.

The direct cost of care for all surgeries ranged from $8286 to $73 727 (median = $21 781; mean = $22 890 ± $6323). Management of comorbidities accounted for a large proportion of the highest cost episodes of care creating extreme outliers in length of stay and pharmacy categories. Circumferential fusions had the highest direct cost of care (median = $29 640; mean = $29 712 ± $5419) and posterior spinal fusions without interbody cage were the lowest cost (median = $18 038; mean = $18 873 ± $4493). Direct costs of care for each approach are represented in Figure 1. The mean direct cost of circumferential fusion was statistically higher than all single approaches (PSF, lateral only, TLIF, and ALIF). For single approach surgery, the cost of posterior spinal fusions without interbody cage was significantly lower than all approaches other than lateral. No significant differences in costs were observed between the lateral approach, TLIF, and ALIF.

Table 4 presents contributions to total direct cost of each cost category for each surgical approach. Supply costs (median = $9366) were the highest category of spending for all fusions using an interbody cage. Supply costs included implants, sterile supplies, and disposables used during the surgery. Implants, including screws, interbody cages, recombinant human bone morphogenetic protein (rh-BMP), and other implants accounted for the highest proportion of supply costs. The cost of implants and other supplies was statistically higher in circumferential fusions compared with all single approaches and significantly lower in posterior spinal fusions without interbody cage compared with all other approaches. ALIF had significantly higher implant/supply costs than TLIF. Differences in supply costs were not significant between lateral and ALIF or lateral and TLIF.

Service costs (median = $8219) were the second highest contributor to direct cost of care for all fusions utilizing an interbody cage, and the highest contributor for PSFs. Operative time was the primary predictor of high service costs. Both operative time and service costs were highest in circumferential fusions. Differences in service costs were statistically significant between all approaches with the exception of the lateral approach compared with ALIF or PSF.

Room and care costs were dependent on the level of acuity for each ward and the patient's length of stay (range 1-19 days, median cost = $2778). The average length of stay ranged from 2.2 days for patients in the lateral group to 4.3 days for patients undergoing circumferential fusion. Room and care costs were significantly higher for circumferential fusions compared with PSF, TLIF, and ALIF. Only 13 patients required ICU admission, but ICU cost was a major contributor to the total cost of care for these patients.

Pharmacy costs contributed the least of all categories, accounting for 4.2% of the direct cost of care. The median pharmacy cost was $739 but contained number of outliers, including 16 patients with pharmacy costs over $2000. The highest costing case was driven by treatment of the patient's hemophilia, including $53 085 in pharmacy costs, primarily for factor VIII replacement. The statistical analysis was performed both with exclusion and inclusion of the extreme outliers with negligible impact on the results. Pharmacy costs were statistically higher for circumferential fusions compared with PSF, TLIF, and ALIF.

Discussion

The results of our study are useful in identifying the composition of cost drivers for single-level lumbar fusions and the variance within these components. Important cost drivers included surgical approach, implants, operating room time, and length of hospital stay. There were statistically significant differences in the mean direct costs between combined circumferential fusions and single approach fusions and between cageless fusion constructs and those using interbody cages (lateral, TLIF, ALIF, and circumferential). Surgical implants, especially the use of an interbody cage, contribute the highest portion of the direct cost for instrumented fusions (Figure 1 and Table 4). There were no differences in cost by diagnosis, including trauma. Furthermore, diagnoses were spread across all approach categories.

One of the most important observations of this study was the prevalence of such high variance in costs among a relatively homogenous cohort of patients. Our analysis shows a nine-fold difference between the highest and lowest cost cases (coefficient of variation = 29.5%) for primary single-level lumbar fusions at the same institution. Such a wide gap is indicative of several factors, which extend far beyond how many implants are used. The cost of implants and osteobiologics vary

Table 2. Clinical Data.

Direct Cost	PSF	Lateral	TLIF	ALIF	Circumferential	All Approaches
OR Time,[a] minutes, mean $\pm$ SD	285 $\pm$ 70	240 $\pm$ 85	309 $\pm$ 75	235 $\pm$ 85	355 $\pm$ 98	299 $\pm$ 84
Length of stay,[b] days, mean $\pm$ SD	3.7 $\pm$ 1.4	2.2 $\pm$ 1.0	3.7 $\pm$ 1.6	3.2 $\pm$ 1.6	4.3 $\pm$ 1.8	3.7 $\pm$ 1.6
ICU admission, n (%)	4 (3.3)	1 (7.6)	4 (1.6)	3 (4.4)	1 (1.4)	13 (2.4)
Total cases, n (%)	124 (23.3)	13 (2.4)	258 (48.5)	68 (12.8)	69 (13.0)	532 (100)

Abbreviations: PSF, posterior spinal fusion; TLIF, transforaminal lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; OR, operating room; ICU, intensive care unit.

[a] Overall *P* of difference in mean OR time by analysis of variance (ANOVA): $P < .0001$. Pairwise comparisons showed statistically significant differences between the following approaches: circumferential with all other approaches, ALIF/PSF, ALIF/TLIF, and lateral/TLIF.

[b] Overall *P* value of difference in mean length of stay by ANOVA: $P = .0009$. Pairwise comparisons showed statistically significant differences between the following approaches: ALIF/circumferential, lateral/circumferential, lateral/PSF, lateral/TLIF.

Table 3. Costs and Variability Within Cost Categories.

Category	% of Total Cost	Variability (% of Cases Utilized)
Supplies	43.8	
Implants	37.2	99.1
Pedicle screws	14.3	88.3
Interbody cages	13.9	76.7
BMP	5.8	25.6
Other[a]	3.2	—
OR instruments	6.6	100
Services	37.6	
OR costs	19.5	100
Neuromonitoring	3.9	55.6
Cell saver	0.6	20.3
Blood bank	0.6	37.6
Fluoroscopy	3.0	93.2
PT/OT	1.7	99.2
PACU	4.8	98.5
Other[b]	3.5	—
Room and care	14.4	
ICU	0.3	2.4
Step-down unit	0.9	5.2
Orthopedic specialty unit	11.0	87.4
Other inpatient room	2.2	5.1
Pharmacy	4.2	
Thrombin	1.7	91.0
Other medications	2.5	100

Abbreviations: BMP, bone morphogenetic protein; OR, operating room; PT/OT, physical therapist/occupational therapist; PACU, post-anesthesia care unit; ICU, intensive care unit.

[a] Other implants include rods, plates, caps, crosslinks, and other bone graft material.

[b] Other services include imaging, respiratory therapy, laboratory tests, pathology, and inpatient dialysis.

depending on contracted rates. With the low standard of evidence required for most orthopedic devices—which come to market through 510(k) clearances—there is a paucity of data available to establish any correlation between the cost of an implant and outcomes achieved. Without standardization in cost across centers, such analysis is infeasible. While this article does not consider clinical outcomes, it wishes to shine a light on the issues that lack of cost transparency presents in advancing evidence-based approaches to care.

We report median costs in our results because of the presence of significant variance including several extreme outliers that disproportionately affect the mean cost. Highly variable costs have been reported in the literature for other types of spinal surgery. A study of hospital charges for single-level anterior cervical discectomy and fusion at a single institution found a range in total charges of \$26 653 to \$129 220[11] and several studies have reported widely variable costs for the treatment of spinal deformity.[12-14] As the health care economy transitions toward alternative payment systems, it is imperative that sources of variance in spine surgery be addressed such that adequate risk stratification measures are in place and consensus is established amongst providers on the most cost-effective manner to deliver care. Being able to predict cost accurately is essential to successfully driving the transition toward bundled payment initiatives. While it is important to restrain the trend of high expenditures in spine surgery, it would be a hazardous interpretation of this article's findings to believe that the authors are advocating for pure cost-minimization. There are indications for which more expensive procedures can be cost-effective by improving the durability of outcomes achieved—spending more upfront to prevent continuous inefficient spending in order to bend the cost curve.

A wide range of costs also suggests high variance in the management of patients that undergo similar procedures. The literature has demonstrated variation between surgeons for various types of spine surgery with regard to recommendations for surgical management, surgical approach, instrumentation, and intraoperative services used.[12,15] Areas of high cost that also exhibit high variance in care between surgeons offer potential targets for building consensus in order to achieve cost savings and quality improvements.

Several intraoperative services demonstrated high variance between practitioners. Cell saver was used in only 20.3% of cases. Cost-effectiveness studies of cell saver in adult lumbar spine surgery have reported mixed results.[16-19] Canan et al[16] found that using cell saver in single-level lumbar fusions did not significantly reduce the need for allogenic blood transfusion and was not cost-effective. Although only a minor contributor to the total cost of care, the use of cell saver is an example of a service that may not be indicated in elective

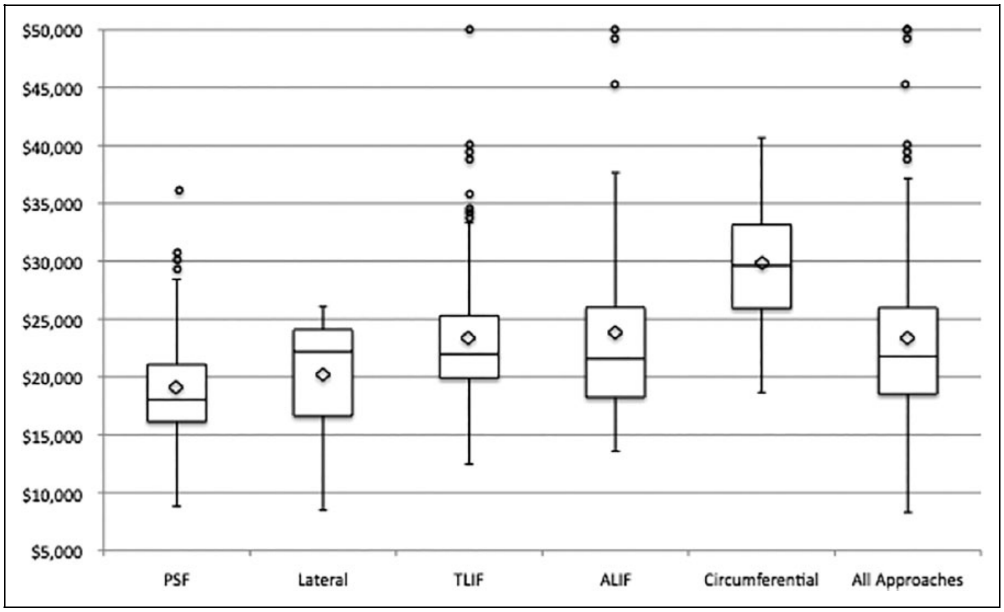

Figure 1. Distribution spread of total direct costs by approach type.

Table 4. Percentage of Total Direct Cost by Cost Category.

Cost Category	PSF	Lateral	TLIF	ALIF	Circumferential	All approaches	P^a (ANOVA)
Supplies	34.3	54.3	43.0	53.6	48.3	43.8	<.0001
Implants[b]	26.9	47.3	37.0	44.7	41.1	37.2	<.0001
Services	43.4	33.1	38.5	30.4	34.3	37.6	<.0001
Room and care	17.6	9.0	14.1	12.8	13.7	14.4	.0004
Pharmacy	4.7	3.6	4.5	3.2	3.7	4.2	.008
Total direct costs	100.00	100.00	100.00	100.00	100.00	100.00	<.0001

Abbreviations: PSF, posterior spinal fusion; TLIF, transforaminal lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ANOVA, analysis of variance.
[a] *P* value for ANOVA of the difference in mean costs between approach types.
[b] Implants are a subcategory of supply costs.

single-level lumbar fusions and is a potential area where cost savings can be achieved by limiting its use.

Operating room time was the longest in circumferential/combined approach fusions and was shortest in the ALIF group. In our facility, a vascular surgeon is used for the approach in the ALIF procedure. As such, the operating room time in anterior procedures can be influenced by the experience of the surgeon performing the approach. There appears to be a relationship in the duration of operating room time and length of hospital stay. Working closely with experienced approach surgeons can help achieve cost savings both in the reduction of operative time and length of stay.

The length of stay was the shortest for lateral fusions and thus room and care costs were the smallest in this group. This may be approach specific as lateral interbody fusions are generally considered in the "minimally invasive" category of surgeries, which are thought to lead to faster recovery time and shorter hospitalizations. Interestingly, the highest ICU admission percentage was with the lateral group, however the authors believe this is driven by outliers in a smaller number of cases (n = 13 out of 532 cases).

The overall rate of neuromonitoring (56%) in this analysis is comparable to other rates cited in the literature.[20] Evidence for the utility of neuromonitoring is more limited for single-level fusions compared with complex spine surgery, and questions remain about cost-effectiveness and indications for the use of neuromonitoring in different types of spine surgery.[21-23] High variance in the use of neuromonitoring indicates that clearer guidelines should be outlined for the use of this service for single-level lumbar fusions. Use of neuronavigation or intraoperative computed tomography scan/3D-fluoro might negate the need of neuromonitoring especially in the setting of single level fusion, however this adds a different cost and possibly more operative time. By not using neuromonitoring, which often requires total intravenous anesthesia (TIVA), the opportunity to use gas anesthesia offers a potential for cost savings as well.

Room and care costs are highly dependent on length of stay and level of care (ie, ICU admission). At our institution, patients undergoing spine surgery are routinely admitted to an orthopedic specialty unit postoperatively, which provides more specialized nursing care at a lower cost than other hospital units. The cost structure and efficiency of care in different hospitals cannot be assumed to be the same. The advantages of specialized orthopedic units—including shorter lengths of stay, lower rates of transfer to the ICU, and lower costs – have been reported in the literature at various institutions.[24-26] Preoperative planning and discussion of postoperative disposition with patients and family prior to surgery can also facilitate the smooth transition from postoperative care to discharge, shortening the duration of a patients stay. Furthermore, the utilization of risk assessment and prediction tools can further facilitate preoperative planning of postoperative care.

In our analysis, implants represented the largest proportion of spending for all surgical approaches except cageless posterior fusions. While variation in the use of implants may be low (eg, pedicle screws were used in 88% of cases in this study), the literature demonstrates a high variation in the costs and charges for orthopedic implants. The total cost for pedicle screws for a single-level fusion in our study varied in cost 6-fold (coefficient of variation = 49%). In a study of 45 academic medical centers, Pahlavan and Bederman[27] found that the price of individual spinal implants varied over 4-fold for pedicle screws and cervical plates to nearly 8-fold for TLIF cages. Furthermore, they found a significant relationship between higher volume of use and lower unit cost of these implants. Multiple factors contribute to the variable costs in spinal implants, including differences in surgeon choices for instrumentation[11,12] and variation in the prices paid by hospitals for the same implant.[27-29] Implant prices between hospitals vary due to confidential purchasing agreements with manufacturers, which present an obstacle to increasing cost awareness among physicians. Similar implants have widely variable costs, as demonstrated by differences in cost between standard pedicle screws and specialty pedicle screws, including cannulated and coated screws. A study by Streit et al[28] found that orthopedic surgeons have poor knowledge of implant costs and frequently underestimate costs. Awareness of implant costs and uniformity of costs for similar implants can significantly reduce cost variance for implants. Reducing variance is an important goal for consistency of cost and for hospital budgeting for spine surgery. Clarifying cost-effective and clinical indications for use of interbody cages, BMP, neuromonitoring, and cell saver might help reduce variance without negatively affecting clinical outcomes.

An important limitation of this report is that we do not consider the clinical outcome of care. The purpose of this article is to promote cost transparency, characterize the determinants of direct costs, and report variance for single-level lumbar fusions. However, the value of interventions encompasses more than simply short-term cost. Porter and Lee[30] suggest that the medical community must shift to track outcomes by condition over the entire cycle of care rather than by individual interventions. In this regard, if a more expensive spine surgery can improve health status and reduce revision surgery rates, postoperative medication utilization, and physical therapy visits more effectively and for a more prolonged period of time than a less expensive surgery, it may actually be cost saving to both the patient and health care system in terms of money, time, and resource utilization. Specifically, there is evidence that circumferential fusion may be cost saving and value enhancing over time, despite having significantly higher direct costs than other surgical approaches in the present study. A cost-utility analysis by Soegaard et al[31] demonstrated that circumferential fusions resulted in improved clinical outcomes and lower long-term costs due to a reduction in the need for additional treatments and revision surgeries compared to posterolateral fusions. In light of this, we have identified a subset of patients from this cohort who have a minimum of 2 years of clinical follow-up and we plan to follow-up this study with an analysis between the costs and surgical outcomes for these patients in a subsequent project.

The authors have also identified several other limitations to this study. We used direct cost data from a single center to generate this descriptive study of direct costs and variance. Our analysis included only direct costs of the index hospital admission; indirect costs, charges, and reimbursements were not addressed. Long-term costs, including costs associated with additional treatments, hospital readmissions, and revision surgeries were not collected. Cost structures and allocation of costs vary between institutions and thus our results may not be widely applicable in terms of the specific distribution of costs. However, the general concept that we present of identifying areas of high cost that also demonstrate high variance is a useful principle in targeting potential areas for cost savings and quality improvements. Furthermore, the authors believe it is inappropriate to focus purely on cost minimization. It is important, however, promote a culture of cost transparency as it is paramount to make strides in addressing many of the issues that plague our health care economy. While the cost of care is an important consideration for our health care system, the primary goal of health care should be to optimize patient value. An examination of both the incremental benefits, including patient-centered quality of life measures and durability of outcomes, and the costs of an intervention over time is necessary in order to measure the true value of an intervention. Finally, health care costs are fluid and can change year to year. The authors did not perform a trend analysis to report changes in costs within the study period and recognize this as a major limitation of the study. Future studies should assess whether the extra cost associated with a surgical approach, device, or service is justified by an incremental improvement in outcomes and long-term value.

Conclusion

There is a lack of consensus on the cost of care for single-level spine fusions. This paper offers transparency into the contributors to an episode of care. There is significant variance in the cost of care for single-level lumbar fusions. This is representative of the high degree of variance for surgical approaches to achieve arthrodesis for lumbar spine pathologies. Implants were the highest contributor to the total cost of care, which increases incrementally with the use of interbody cages and osteobiologics. Other significant contributors to the cost of care

are service costs and length of hospital stay. Further work is necessary to determine whether a correlation exists between cost of care and outcomes achieved.

Appendix A

Current Procedural Terminology (CPT) Codes

CPT Code	Description
Inclusion criteria	
22558	Arthrodesis: Anterior interbody: with diskectomy: Single level; lumbar
22612	Arthrodesis: Posterior/posterolateral: Single level; lumbar
22630	Arthrodesis: Posterior interbody with laminectomy/ diskectomy: Single interspace; lumbar
Exclusion criteria	
22532	Arthrodesis: Single level, lateral: Thoracolumbar
22534	Arthrodesis: Single Level, Lateral: Thoracolumbar: Each additional segment
22556	Arthrodesis: Single level, lateral: Thoracic: Each additional segment
22610	Arthrodesis: Single level, posterior: Thoracolumbar
22614	Arthrodesis: Single level, posterior/posterolateral; lumbar: Each additional segment
22802	Arthrodesis: Posterior: Spinal deformity: with/without cast; 7 to 12 vertebral segments
22804	Arthrodesis: Posterior: Spinal deformity; 13+ vertebral segments
22810	Arthrodesis: Single level, posterior/posterolateral: Thoracic
22812	Arthrodesis: Single level, posterior/posterolateral: Thoracic: Each additional segment

Authors' Note

This study was approved by the UCSF Institutional Review Board. Its contents are solely the responsibility of the authors.

Declaration of Conflicting Interests

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References

1. Martin BI, Deyo RA, Mirza SK, et al. Expenditures and health status among adults with back and neck problems. *JAMA*. 2008; 299:656-664.
2. Katz JN.Lumbar spinal fusion. Surgical rates, costs, and complications. *Spine (Phila Pa 1976)*. 1995;20(24 suppl):78S-83S.
3. Deyo RA, Gray DT, Kreuter W, Mirza S, Martin BI. United States trends in lumbar fusion surgery for degenerative conditions. *Spine (Phila Pa 1976)*. 2005;30:1441-1445.
4. United States Bone and Joint Initiative. *The Burden of Musculoskeletal Diseases in the United States*. 2nd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2011.
5. Abraham DJ, Herkowitz HN, Katz JN. Indications for thoracic and lumbar spine fusion and trends in use. *Orthop Clin North Am*. 1998;29:803.
6. Deyo RA, Mirza SK. Trends and variations in the use of spine surgery. *Clin Orthop Relat Res*. 2006;443:139-146.
7. Weinstein JN, Lurie JD, Olson PR, Bronner KK, Fisher ES. United States' trends and regional variations in lumbar spine surgery: 1992-2003. *Spine (Phila Pa 1976)*. 2006;31:2707-2714.
8. Deyo RA, Mirza SK. The case for restraint in spinal surgery: does quality management have a role to play? *Eur Spine J*. 2009; 18(suppl 3):331-337.
9. Indrakanti SS, Weber MH, Takemoto SK, Hu SS, Polly D, Berven SH. Value-based care in the management of spinal disorders: a systematic review of cost-utility analysis. *Clin Orthop Relat Res*. 2012;470:1106-1123.
10. Kepler CK, Wilkinson SM, Radcliff KE, et al. Cost-utility analysis in spine care: a systematic review. *Spine J*. 2012;12:676-690.
11. Epstein NE, Schwall G, Reillly T, Insinna T, Bahnken A, Hood DC. Surgeon choices, and the choice of surgeons, affect total hospital charges for single-level anterior cervical surgery. *Spine (Phila Pa 1976)*. 2011;36:905-909.
12. Sanders JO, Haynes R, Lighter D, et al. Variation in care among spinal deformity surgeons: results of a survey of the Shriners hospitals for children. *Spine (Phila Pa 1976)*. 2007;32:1444-1449.
13. Kamerlink JR, Quirno M, Auerbach JD, et al. Hospital cost analysis of adolescent idiopathic scoliosis correction surgery in 125 consecutive cases. *J Bone Joint Surg Am*. 2010;92:1097-1104.
14. Daffner SD, Beimesch CF, Wang JC. Geographic and demographic variance of cost and surgical treatment of idiopathic scoliosis. *Spine (Phila Pa 1976)*. 2010;35:1165-1169.
15. Irwin ZN, Hilibrand A, Gustavel M, et al. Variation in surgical decision making for degenerative spinal disorders. Part I: lumbar spine. *Spine (Phila Pa 1976)*. 2005;30:2208-2213.
16. Canan CE, Myers JA, Owens RK, et al. Blood salvage produces higher total blood product costs in single-level lumbar spine surgery. *Spine (Phila Pa 1976)*. 2013;38:703-708. doi:10.1097/BRS.0b013e3182767c8c.
17. Reitman CA, Watters WC 3rd, Sassard WR. The cell saver in adult lumbar fusion surgery: a cost-benefit outcomes study. *Spine (Phila Pa 1976)*. 2004;29:1580-1584.
18. Chanda A, Smith DR, Nanda A. Autotransfusion by cell saver technique in surgery of lumbar and thoracic spinal fusion with instrumentation. *J Neurosurg*. 2002;96(3 suppl):298-303.
19. Savvidou C, Chatziioannou SN, Pilichou A, Pneumaticos SG. Efficacy and cost-effectiveness of cell saving blood autotransfusion in adult lumbar fusion. *Transfus Med*. 2009;19:202-206.
20. Hamilton DK, Smith JS, Sansur CA, et al. Rates of new neurological deficit associated with spine surgery based on 108 419 procedures: a report of the scoliosis research society morbidity and mortality committee. *Spine (Phila Pa 1976)*. 2011;36:1218-1228.

21. Ney JP, van der Goes DN, Watanabe JH. Cost-effectiveness of intraoperative neurophysiological monitoring for spinal surgeries: beginning steps. *Clin Neurophysiol*. 2012;123:1705-1707.
22. Fehlings MG, Brodke DS, Norvell DC, Dettori JR. The evidence for intraoperative neurophysiological monitoring in spine surgery: does it make a difference? *Spine (Phila Pa 1976)*. 2010; 35(9 suppl):S37-S46.
23. Wiedemayer H, Fauser B, Sandalcioglu IE, Schäfer H, Stolke D. The impact of neurophysiological intraoperative monitoring on surgical decisions: a critical analysis of 423 cases. *J Neurosurg*. 2002;96:255-262.
24. Batsis JA, Naessens JM, Keegan MT, Huddleston PM, Wagie AE, Huddleston JM. Cost savings of hip arthroplasty patients on specialized orthopedic surgery units. *Am J Orthop (Belle Mead NJ)*. 2009;38:E5-E11.
25. Batsis JA, Naessens JM, Keegan MT, Huddleston PM, Wagie AE, Huddleston JM. Resource utilization of total knee arthroplasty patients cared for on specialty orthopedic surgery units. *J Hosp Med*. 2008;3:218-227.
26. Esoga PI, Seidl KL. Best practices in orthopaedic inpatient care. *Orthop Nurs*. 2012;31:236-240.
27. Pahlavan S, Bederman S. *Variations in costs of spinal implants [abstract]. Paper presented at: American Academy of Orthopaedic Surgeons 2013 Annual Meeting; March 19-23*, 2013; Chicago, IL.
28. Streit JJ, Youssef A, Coale RM, Carpenter JE, Marcus RE. Orthopaedic surgeons frequently underestimate the cost of orthopaedic implants. *Clin Orthop Relat Res*. 2013;471:1744-1749. doi:10.1007/s11999-012-2757-x.
29. Roach JW, Mehlman CT, Sanders JO. Does the outcome of adolescent idiopathic scoliosis surgery justify the rising cost of the procedures? *J Pediatr Orthop*. 2011;31(1 suppl):S77-S80. doi:10.1097/BPO.0b013e3181f73bfd.
30. Porter ME, Lee TH. The strategy that will fix healthcare. *Harvard Business Rev*. 2013;91:50-70. doi:10.2013.
31. Soegaard R, Bünger CE, Christiansen T, Høy K, Eiskjaer SP, Christensen FB. Circumferential fusion is dominant over posterolateral fusion in a long-term perspective: cost-utility evaluation of a randomized controlled trial in severe, chronic low back pain. *Spine (Phila Pa 1976)*. 2007;32:2405-2414.